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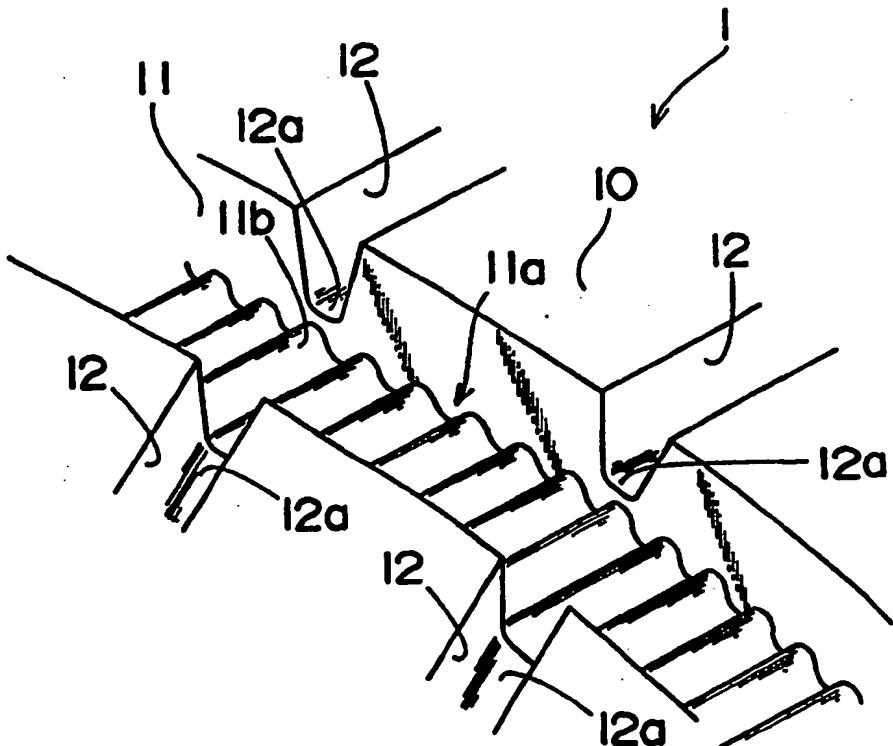
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## (54) Title: TIRE FOR VEHICLE

## (57) Abstract

A tire (1) wherein at least a circumferential groove (11) of grooves formed in a tread surface (10) comprises a continuously waved bottom surface whose top does not reach the tread surface, which extends partially or entirely along the circumference of the groove. The tire of this invention may prevent a holding of water due to its groove, increasing the ability to discharge water. It is therefore possible to retain grip performance of the tire. Particularly when traveling in rain, the tire effects a reliable hydroplaning prevention avoiding an increase in the proportion of the groove.



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## DESCRIPTION

### TIRE FOR VEHICLE

#### TECHNICAL FIELD

This invention relates to a tire for vehicle, and  
5 more particularly to a tire for vehicle capable of assuredly  
preventing the so-called hydroplaning phenomenon.

#### BACKGROUND ART

A normal tire has grooves defined as tangentially  
and circumferentially extending in its tread surface.

10 One of the purposes for providing grooves in the  
tread surface is to prevent hydroplaning phenomenon where a  
vehicle traveling at high speed on a road covered with water,  
slips and spins because of a layer of water formed between the  
tires and a road surface. Specifically, one of the major  
15 objects of providing grooves in the tread surface is to  
minimize the amount of water present between the road surface  
and the tire surface excluding the grooves by collecting the  
water into the grooves, thereby preventing the hydroplaning.  
The water collected in the grooves is discharged out of the  
20 grooves from the respective openings.

A circumferential groove (hereinafter referred to as  
"longitudinal groove") of the grooves defined in the tread  
surface is normally wider and deeper than a tangential groove  
(hereinafter referred to as "transverse groove"). This allows  
25 water collected by the transverse groove to be introduced into

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the longitudinal groove, then discharged out of the longitudinal groove from its opening.

To what extent the grooves of the tire can prevent the hydroplaning largely depends upon the abilities of the 5 grooves to collect water and to discharge water thus collected from the respective openings.

The ability of each groove to collect water is proportional to its capacity. The ability of each groove to discharge the collected water from its opening is proportional 10 to a surface area of the opening. Therefore, as the proportion of grooves relative to the tread surface increases, both abilities increase. This, however, decreases the contact area between the tire and the road surface, decreasing grip performance.

15 Consequently, an ideal tire is one which has a large contact area with respect to the road surface for assuring a high grip performance and which defines grooves as having excellent abilities to collect water therein and to discharge water from its openings.

20 For such an ideal tire to be realized, there have been proposed various tires having different groove patterns.

It is generally considered that the provision of 25 longitudinal groove with an unchanged width and an increased depth, in particular, would be effective in enhancing the ability to collect water while holding the grip performance

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maintained. Hence, this is generally and widely practiced.

Also, there has been proposed a tire having a herringbone-like pattern where a wide, deep and straight longitudinal groove is provided as extending centrally of the 5 tire and V-shaped transverse grooves are formed as inclined on opposite shoulders of the longitudinal groove so that water collected by the transverse grooves can be efficiently introduced into the longitudinal groove and efficiently discharged out of the tire from the opening of the 10 longitudinal groove (see Japanese Patent Unexamined Publication No. 5-178019 (1993), page 2, second column, lines 18-22).

Further, there has been proposed another type of tire wherein a longitudinal groove of grooves formed in a 15 tread surface has a web therein which extends from the bottom of the longitudinal groove to a road surface, and when a tire rotates, the web removes a water layer ahead of the tire in the rear of the tire to reduce the amount of water in a contact area between the tire and the road, thereby preventing 20 the hydroplaning (see Japanese Patent Unexamined Publication No. 48-6402 (1973), page 2, upper right column line 2 to lower left column line 3).

However, a study carried out by the inventors has found that any of the aforementioned conventional tires has no 25 measure to prevent the holding of water being a factor of the

hydroplaning, failing to prevent the hydroplaning.

The higher the rotation speed of a tire is, the less time is allowed for the tire to discharge water in the groove. As a result, the tire makes one revolution before fully 5 discharging the water, returning the retained water ahead of the tire (which is called "holding of water by groove").

If the holding of water occurs, water is accumulated between the tire and the road surface, whose amount exceeds the water present in the road surface. Then, if the amount of 10 water thus accumulated exceeds the abilities of the groove to collect water and to discharge the water thus collected from the openings, a thicker layer of water is formed between the tire and the road surface to cause the hydroplaning.

The inventors have studied the effect of the holding 15 of water on the conventional tires of the herringbone-like pattern and the like, and have had the following findings. As a tire has a narrower, deeper groove, it has a lower ability to discharge collected water out of the grooves from its opening, thus requiring a longer time. Particularly, as the 20 rotation speed of the tire increases, the groove holds more water, canceling the action of the groove pattern to prevent the hydroplaning, as previously described.

It has also found that a tire involved in the holding of water suffers from an increased rolling resistance 25 due to the presence of a large amount of water in the

- 5 -

direction of traveling.

On the other hand, in the tire provided with the web, the longitudinal groove is divided by the web, so that the capacity of each divided longitudinal groove is 5 restricted. This shows that if the amount of water present on a road exceeds the aforesaid limited capacity, or if water whose amount exceeds the aforesaid capacity flows into the longitudinal groove through the transverse groove communicated therewith, the aforesaid web's action on the road surface is 10 canceled, causing the hydroplaning.

It is, therefore, the object of this invention to provide a tire for vehicle that prevents grooves from holding water, to realize a more reliable prevention of hydroplaning and to reduce rolling resistance, particularly in traveling in 15 rain.

#### DISCLOSURE OF THE INVENTION

To attain the aforesaid object, the tire for vehicle of this invention is characterized in that at least a longitudinal groove of grooves formed in a tread surface 20 comprises a continuously waved bottom surface whose top does not reach the tread surface, which extends partially or entirely along the circumference of the groove.

Preferably, the waved bottom surface extends over the entire width of the longitudinal groove.

25 Although not particularly limited to the following,

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the waved bottom surface is preferably in a wave form selected from the group consisting of a sine wave form, a square wave form, a chopping wave form and a trapezoidal wave form.

5 The wave form is not particularly limited in size but preferably has a wave height ranging from 1 to 4 mm and a wave length ranging from 1 to 150 mm.

10 In the tire for vehicle of this invention, it is preferable that some or all of said grooves formed in said tread surface including grooves having said waved bottom surface are each treated as having water repellency on at least a part of the bottom or side surfaces thereof.

15 To treat the bottom or the side surfaces of the groove as having water repellency, it is desirable to form a coating film containing a water repellent resin thereon, to affix a sheet containing a water repellent resin thereto, or to form groove-defining portions by a rubber compound containing a water repellent resin at the time of vulcanization and forming of the tire.

20 According to the knowledge of the inventors, the holding of water by groove results from that when a vehicle is traveling at high speed, water rapidly compressed by its tire and a road surface behaves like a solid matter in a groove, thus making it difficult to discharge water out of the tire from an opening of a longitudinal groove.

25 Even under the condition where the holding of water

occurs, there is a flow of water in the longitudinal groove. That is, water in the longitudinal groove rotates in the same direction with a little delay relative to the rotation of the tire by inertial force due to the rotation of the tire, 5 resulting in a difference in rotary speed between the two. This allows the water to flow in the longitudinal groove.

Therefore, if at least the bottom of the longitudinal groove comprises a continuously waved bottom surface whose top does not reach the tread surface, which 10 extends partially or entirely along the circumference of the groove, a wave form of the waved bottom surface, in association with the rotation of the tire, serves to impart a flow of water in the longitudinal groove with a wave motion directed radially outwardly of the tire. The impact of the 15 wave motion divide the water held in the groove into small lumps. Then, the water is rapidly discharged out of the groove by the wave motion and the centrifugal force due to the rotation of the tire.

As the rotation speed of the tire increases, less 20 time is allowed to discharge water in the groove, whereas the frequency of the wave motion generated by the wave form increases, as previously described. Consequently, the water held in the groove is divided into further smaller lumps 25 compared to the case where the tire rotates at lower speed, and then rapidly discharged out of the groove by a greater

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centrifugal force. As a result, almost same effect may be obtained at any one of speeds ranging from low to high.

Therefore, the tire of this invention can assuredly prevent the hydroplaning and reduce its rolling resistance.

5 If the top of the waved bottom surface of the longitudinal groove levels with the tread surface, the flow of water in the longitudinal groove is hindered, thus failing to develop the aforesaid effect of the wave form. In addition, such a construction would suffer the same problem as in the 10 aforesaid tire having webs. Accordingly, it is essential that the top of the waved bottom surface does not reach the tread surface in order not to hinder the flow of water in the longitudinal groove.

15 If some or all of the grooves formed in the tread surface including the longitudinal groove are treated such that at least a part of the bottom or a part of the side surfaces has water repellency, surface tension inherent to water may promote water in the groove turning into droplets. Therefore, the water may be discharged out of the groove even 20 faster. This further increases the effects of preventing the hydroplaning and of decreasing rolling resistance.

25 As a similar construction to the tire for vehicle of this invention, Japanese Patent Unexamined Publications No. 5-238210 (1993) and No. 5-238211 (1993) disclose a tire wherein side surfaces of a longitudinal groove are formed as having a

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waved surface.

With this construction, however, the wave motion imparted to water in the groove is not directed radially outwardly of the tire but toward a direction orthogonal to the 5 above direction, and therefore the effect of discharging water out of the groove is insufficient.

Japanese Utility Model Unexamined Publication No. 5-76804 (1993) discloses a tire wherein plural projections for use as a spike are provided at regular intervals on a 10 longitudinal groove (a groove for water discharge) extending centrally of the width of a tread surface of the tire.

With this construction, however, the projections for use as a spike are not provided in a continuous form as shown in Fig. 2 of the aforesaid Publication. There would occur no 15 wave motion effective to divide water held in the groove into small lumps, resulting in little effect of discharging water out of the groove.

Japanese Patent Unexamined Publication No. 6-239108 (1994) discloses a tire wherein a projection for preventing 20 pebble clogging (a projection against pebble clogging) is formed on the bottom of a longitudinal groove, while a projection (a transverse projection) for assisting the aforesaid projection against pebble clogging is formed on a side surface of the same.

Both kinds of projections, however, are not provided 25

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over the entire width of the bottom of the longitudinal groove. Therefore, some portions of the water flow in the groove are imparted with a wave motion while the rest is not, resulting in insufficient effect of discharging water out of 5 the groove.

As stated above, with any of the conventional tire constructions, it is impossible to obtain the same effect as in this invention.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

10 Fig. 1 is an enlarged perspective view illustrating a longitudinal groove as a principal part of the tire for vehicle of this invention.

15 Fig. 2(a) is a cross-sectional view illustrating the above longitudinal groove. Fig. 2(b) is a longitudinal section illustrating the above longitudinal groove.

20 Fig. 3(a) is a further enlarged longitudinal section illustrating the wave form at a waved bottom surface of the above longitudinal groove. Figs. 3(b) and 3(c) are each a longitudinal section illustrating another example of the wave form of the waved bottom surface of the longitudinal groove.

Figs 4(a) and 4(b) are each a longitudinal section illustrating another example of the groove form of the longitudinal groove.

25 Fig. 5(a) to 5(d) are each a longitudinal section illustrating a state where the bottom surface of the

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longitudinal grooves being in a wave form is treated as having water repellency.

Fig. 6 is a schematic diagram illustrating an apparatus used for the measurement of the water discharge ability of each tire for vehicle of Examples and Comparative Example.

Fig. 7 is an elevation view illustrating another apparatus used for the measurement of the water discharge ability of each tire for vehicle of Examples and Comparative Example.

Fig. 8 is a sectional view illustrating a pail for collecting water discharged from grooves of a tire which is included in the apparatus in Fig. 7.

Fig. 9 is a side view illustrating a state where a brush of the apparatus in Fig. 7 is brought into contact with a tire and a roller.

#### BEST MODE FOR CARRYING OUT THE INVENTION

The tire for the vehicle of this invention will be described with reference to the drawings illustrating an example thereof.

As shown in Fig. 1, 2(a) and 2(b), a tire for vehicle 1 of this invention includes, in its tread surface 10, a longitudinal groove 11 extending in the circumferential direction and a transverse groove 12 extending in the tangential direction. In the example shown, a bottom 11a of

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the longitudinal groove 11 is in the form of a continuous wave.

The bottom of the transverse groove 12 is not in the form of a wave, but if necessary, every bottom of the grooves 5 on the tread surface 10 including the longitudinal groove 11 and the transverse groove 12 may be in the form of a wave. However, as evident from the aforesaid principle of 10 discharging water present in the groove, the formation of such waved surface is most effective for the longitudinal groove 11.

In view of the effect of discharging water, the longitudinal groove 11 may preferably have a wave form surface extending over the entire width of the bottom 11a.

Again in view of the effect of discharging water, 15 the longitudinal groove 11 may preferably have a wave form surface extending over the entire circumference of the bottom 11a. Depending on the case, however, the wave form need not necessarily be provided over the entire circumference of the bottom 11a of the longitudinal groove 11. More specifically, 20 the bottom 11a of the longitudinal groove 11 may include a waved surface portion and a flat surface portion arranged either regularly order or at random, thus being an intermittent wave.

Examples of the wave form include a square wave, a 25 chopping wave and a trapezoidal wave, each occurs regularly,

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as shown in Figs. 3(b), 3(c) and 4(a) as well as a sine wave shown in Figs. 1 and 3(a), which are preferred in terms of processibility.

5      Besides the above known examples, there may employ various successive forms such as a combination of the waves shown in Fig.s 3(a) to 3(c) and Fig. 4(a). A typical pattern is one comprising the sine wave and the chopping wave as shown in Fig. 4(b).

10     As described above, the top 11b of the waved surface must be arranged so as not to reach the tread surface 10.

15     Although its wave height (designated by reference character h in Figs. 3(a) to 3(c) and Figs. 4(a) and 4(b)) is not particularly limited in this invention, it is preferably in a range of from 1 to 4 mm. If the wave height exceeds 4 mm, it might accelerate the holding of water, particularly at high rotation speed, likewise in the groove having the web. On the other hand, if the wave height is less than 1 mm, wave motion produced in the groove might be too weak to offer a sufficient effect of dividing water in the groove into small lumps.

20     It is particularly preferable that the wave height is in a range from 2 to 3.5 mm, more preferably a range from 2 to 3 mm.

25     Since the longitudinal groove 11 is required to be deeper than the transverse groove 12 such that water collected by the transverse groove 12 may flow thereinto, the top 11b of

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the waved surface on the bottom 11a of the longitudinal groove 11 is preferably lower than the bottom 12a of the transverse groove 12, as shown in Figs. 1, 2(a) and 2(b).

5 The wave height of the wave form surface is preferably made constant for a simplified construction, but if the wave form surface is also provided on other grooves than the longitudinal groove 11, whose wave height may differ depending on its depth and action. It is also possible to modify the wave height within a single groove.

10 The wave length of the wave form surface (designated by reference character f in Figs. 3(a) to 3(c) and 4(a) and 4(b)) is preferably in a range of from 1 to 150 mm. If the wave length exceeds 150 mm, the frequency of a wave motion produced in the groove might be too low to offer a sufficient 15 effect of dividing water into small lumps. On the other hand, if the wave length is less than 1 mm, the frequency of a wave motion produced particularly at high rotation speed might be too high to offer sufficient effect of dividing water into small lumps.

20 It is particularly preferable that the wave length of the wave form surface ranges from 1 to 50 mm, more preferably from 5 to 15 mm.

25 The wave length of the wave form is preferably made constant for a simplified construction, but if the wave form surface is also provided on the bottoms of other grooves than

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the longitudinal groove 11, the respective wave length of the grooves may differ depending on its depth and action.

In particular, the wave length of the wave form surface on the bottom 11a of the longitudinal groove 11 is closely related to the rotation speed of the tire. If the wave length is constant throughout the wave form surface, there is a possibility that the wave motion generated from the wave form surface be synchronized with the rotation speed of the tire and the frequency of water vibration, thus lowering the effect of dividing water into small lumps. To overcome this problem, the wave length of the wave form surface on the bottom 11a of the longitudinal groove 11 may be varied regularly or irregularly, or otherwise, several kinds of wave form surfaces having different lengths may be provided in parallel on the bottom 11a of the longitudinal groove 11. If the bottom 11a of the longitudinal groove 11 has an intermittent wave form surface as described above, the respective wave length of the wave form surface portions may differ.

In view of efficiency and productivity, it is desired to form the waved bottom surface of the groove at the time of the formation of a rubber tire by arranging that in a mold for vulcanization and forming of the tire, the surface of a portion to be groove is in a wave form. Otherwise, the bottom of the groove may have a wave surface by cutting the

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corresponding portion to be groove in a formed tire, or by affixing a wave-formed rubber belt to the bottom of the groove.

In order to conduct a water-repellent treatment to 5 at least a part of the bottom or a part of side surfaces of some or all of the grooves formed in the tread surface including the groove having the waved bottom surface, the corresponding part to be groove may be composed of a water repellent resin.

10 As a specific example of the water repellent treatment, any of the following methods (A) through (C) is appropriate.

(A) As shown in Fig. 5(a), for example, a coating film F containing a water repellent resin is formed on the 15 corresponding portion to be treated as having water repellency (i.e. the waved bottom surface 11a of the groove shown).

(B) As shown in Fig. 5(b), for example, a sheet S1 containing a water repellent resin is affixed to the corresponding portion to be treated as having water repellency 20 (i.e. the bottom 11a).

(C) As shown in Fig. 5(d), for example, when a tire is vulcanized and formed, the corresponding portion to be treated as having water repellency (i.e. the bottom 11a) is composed of a rubber compound containing a water repellent resin.

25 The coating film F used in the method (A) is formed

by applying a coating agent wherein the water repellent resin is dissolved or dispersed in an appropriate solvent, to the corresponding portion to be groove in a rubber tire produced beforehand, following by drying. If a curing-type coating 5 agent is used, the coating agent may be cured by heating or irradiation of ultraviolet rays after dried or during drying.

Examples of water repellent resins for use in the coating film include a silicone resin, a fluorine resin such as polytetrafluoroethylene, and an ultra-high polymeric 10 polyethylene.

The coating film is not particularly limited in thickness, but has a preferable thickness ranging from 5 to 800  $\mu\text{m}$ . If the thickness of the coating film is less than the aforesaid range, a sufficient water repellency might not be 15 obtained. No problem occur when traveling at a normal road, but when traveling on a rough road or off-road, there is a fear that the coating film frays in a very short period of time, losing its water repellency. On the other hand, if the thickness of the coating film exceeds the aforesaid range, 20 there is a fear that the coating film becomes rigid and fails to fully follow the rubber deformation to cause a crack or a peel, losing its water repellency.

It is particularly preferable that the thickness of the coating film is in a range of from 8 to 800  $\mu\text{m}$ , more 25 preferably from 20 to 800  $\mu\text{m}$ .

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The above method (A) has the advantage of easier operation because its water repellency can be obtained merely by applying a coating agent to form a coating film. This method also has the advantage that even when the water repellent effect is lost due to the fray of the coating film, such effect can be restored by applying the coating agent again to form a new coating film.

As for the sheet S1 used in the method (B), there may employ a sheet prepared by the following manner. Specifically, a mixture containing a water-repellent resin and an additive such as stabilizer, if necessary, is formed into a sheet and is cut into a proper size.

Water repellent resins for use in the sheet are preferably rubber resins such as silicone rubber and fluorine rubber, which allow the sheet to follow the rubber deformation.

The sheet is not particularly limited in thickness, but has a preferable thickness ranging from 0.04 to 1 mm. If the thickness of the sheet is less than the aforesaid range, it might be impossible to impart sufficient durability to the sheet, causing a fray of the sheet in a very short period of time, losing its water repellency. If the thickness of the sheet exceeds the aforesaid range, there is a fear that the sheet becomes rigid and fails to fully follow the rubber deformation to cause a crack or a peel, losing its water

repellency.

Where the sheet S1 is affixed to the waved bottom 11a of the groove as shown in Fig. 5(b), if the wave length of the wave form is too short or if the sheet is too thick, it 5 would be difficult to conformably affix the sheet to the surface of small wave form. To overcome this problem, there may use a sheet preliminarily made in the form of wave corresponding to the waved surface. Alternatively, as shown in Fig. 5(c), the surface of a sheet S2 to be affixed thereto 10 may be in the form of wave. In this case, the surface of the sheet 2 substitutes for the waved bottom 11a of the groove instead of the bottom 11a'.

For affixing the sheet to the bottom of the groove, an adhesive particularly excellent in making a water repellent 15 resin adhere to rubber may be selected from various known adhesives.

The sheet thus obtained has the advantages of higher durability than the coating film. In addition there is the advantage that when the sheet has a crack or a peel, a new 20 sheet can be affixed to the portion of the crack or the peel, thereby restoring its water repellency.

In the method (C) where the portion to be imparted with water repellency is composed of a rubber compound containing a water repellent resin when the tire is vulcanized 25 and formed, it is preferable to add powder of the water

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repellent resin into the same rubber compound used in other members of the tire instead of a carbon black, for example, or to mix thereto water repellent resin having a good compatibility with the rubber compound. Alternatively, a 5 rubber compound mainly composed of the aforementioned water repellent rubber may be used.

The water repellent surface formed by said method (C) has the advantage of even higher durability than the coating film or the sheet.

10 The methods (A) to (C) may be used in combination. For example, if a surface treated as having water repellency by the method (C) is further formed with the coating film of the method (A) or further affixed with the sheet of the method (B), its water repellency may last even longer.

15 Alternatively, any of the methods (A) to (C) may be selected and used depending on the portion given the water repellency treatment.

20 The constitution of this invention is applicable to every kind of tire for vehicle having grooves in its tread surface such as a tire having a normal tube, a tubeless tire and a solid tire. This constitution may be most effectively applied to a tire for use in automobiles that travel on a road at high speed, but it is also applicable to a rubber tire for use in various vehicles including those used in landing gears 25 of air crafts, new traffic systems or monorails, those for

agricultural use such as tractors, those for industrial use such as machine tools, and bicycles, among others.

The groove pattern of the tread surface is not particularly limited. In addition to a typical pattern comprising the longitudinal groove and the transverse groove, there may employ any of patterns including one where, as described above, there is no change in the width of the longitudinal groove but its depth is increased, or one where a wider, deeper straight line-like longitudinal groove is formed at the center of the tire and also V-shaped transverse grooves are formed as inclined on opposite shoulders of the longitudinal groove.

If the constitution of this invention is applied to such groove patterns being devised to improve the water collecting ability of the groove, it is possible to further improve the ability of the groove to discharge collected water from its opening while avoiding the holding of water by the groove, which has not been solved by the known tires.

Accordingly, this invention effects more reliable the

hydroplaning prevention.

#### **INDUSTRIAL APPLICATION**

According to the tire for vehicle of this invention, as previously described in details, the waved surface which is provided in at least some or all parts of the bottom of the longitudinal groove, divides water in the groove into small

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lumps, allowing the water to be promptly discharged out of the groove. Therefore, the tire for vehicle of this invention can prevent a groove from holding water to effect a reliable prevention of the hydroplaning, particularly when traveling in rain, and to reduce the rolling resistance of the tire.

#### EXAMPLES

This invention will be described with reference to Examples and Comparative Example, which are may shown by way of example.

10

#### Example 1

A synthetic rubber was formed and vulcanized to prepare a synthetic rubber belt whose surface is in the form of a sine wave of 4 mm wide, 3.5 mm thick(max.), 3 mm in wave height h and 5 mm in wave length f.

15

Using a synthetic rubber adhesive(Tradename "Bondo Sokkan G Kuriya", manufactured by Konishi Co., Ltd.), the belt was affixed to the bottom of a longitudinal groove (4 mm wide, 6 mm deep) of a commercially available tire for automobile (Tradename "SCIENCE S-780" whose diameter is 500 mm, manufactured by The Yokohama Rubber Co. Ltd.) over the entire circumference thereof. There obtained a tire of Example 1 wherein a sine wave was formed on the bottom of the longitudinal groove over its entire circumference.

20

#### Example 2

25

A coating agent containing a silicone resin

(Tradename "TSE322", manufactured by Toshiba Silicone Co. Ltd.) was applied to the bottom and both side surfaces of a longitudinal groove of a tire wherein the sine wave was formed, in the same manner as in Example 1, on the bottom of 5 the longitudinal groove over its entire circumference (wave height  $h$  and wave length  $f$  were the same as in Example 1), and then the coating agent thus applied was dried to form a coating film (100  $\mu\text{m}$  thickness). Thus obtained a tire of Example 2 wherein the bottom and both side surfaces of the 10 longitudinal groove was treated as having water repellency.

The following Comparison Test 1 was conducted on the tires of Examples 1, 2 and an unprocessed tire for comparison (Comparative Example 1) wherein the bottom of a longitudinal groove was flat and neither the bottom nor side surfaces thereof were treated as having water repellency, to evaluate 15 the respective characteristics.

#### **Comparison Test 1**

As shown in Fig. 6, a tire 1 of each sample was mounted on a rotation wheel 2, and a roller 3 made of 20 polyurethane rubber (250 mm in diameter, 120 mm wide) was pressed thereagainst from downward so that the distance between the shafts of the two became 4 mm shorter than the distance when the two came in contact with each other.

While maintaining this pressed state, the tire 1 and 25 the roller 3 were rotated respectively in the directions shown

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by arrows in the figure with the number of revolutions of the tire 1 set at 970 r.p.m. (equivalent to 80 km/h). When the rotation was stable, while feeding 13 liter of water per minute between the tire 1 and roller 3 by means of a gutter 4 (size of the feed port: 5 mm high, 90 mm wide), a pail 5 (size of the opening: 230 mm long, 230 mm wide) was placed 5 mm forward from the tire 1 to measure the amount of water (cc) collected by the pail 5 in 30 seconds.

The test results are given in Table 1.

A decrease rate of water (%) with respect to each of Examples 1 and 2, based on the result of Comparative Example 1 was obtained by the following equation. The results are also given in Table 1.

$$15 \quad DR (\%) = \frac{(CE) - (E)}{(CE)} \times 100$$

wherein DR denotes the decrease rate of water, CE denotes the amount of water collected in Comparative Example, and E denotes the amount of water collected in Example 1 or 2.

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TABLE 1

	Water (cc)	Decrease rate (%)
Example 1	576	14
Example 2	482	28
Comp. Ex. 1	670	-

5

As shown in Table 1, both Example 1 and Example 2 collected much less water in the pail than Comparative Example 1. This shows that both tires of Examples 1 and 2 are excellent in discharging water out of the groove and that both can significantly reduce the amount of water which is not discharged from the groove but is transmitted forward in the rotational direction.

If comparison is made between Examples 1 and 2, Example 2 wherein a water repellent coating film was formed on the bottom and both side surfaces of the groove, collected less water than Example 1, resulting in a greater decrease rate of water (%) than Example 1. This shows that Example 2 are far more excellent in discharging water.

Next, a full-scale Comparison Test 2 (described later) was conducted on Comparative Example 1 and the following Examples to evaluate the respective characteristics more specifically.

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### Example 3

Using a commercially available rubber tire for automobile being the same type as used in Examples 1 and 2, the bottom of a longitudinal groove was shaved by 4 mm wide and 3 mm deep over its entire circumference, to which an 5 unvulcanized synthetic rubber belt (4 mm wide, 3 mm thick) was affixed using a rubber glue of the same type.

Then, the belt was subjected to press molding using a mold and was vulcanized to prepare a tire of Example 3 10 wherein the bottom surface of the longitudinal groove was in the form of a sine wave (2 mm in wave height  $h$ , 5 mm in wave length  $f$ ) as shown in Figs. 1, 2(a), 2(b) and 3(a).

### Examples 4

A tire of Example 4 was prepared in the same manner 15 as in Example 3, except that the wave length  $f$  of the sine wave was varied to 15 mm using another mold for press molding. Its wave height  $h$  was same as Example 3.

### Example 5

A coating agent containing a silicone resin 20 (Tradename "TUV6000", manufactured by Toshiba Silicone Co. Ltd.) was applied to the bottom and both side surfaces of a longitudinal groove of a tire wherein a sine wave (wave height  $h$  and wave length  $f$  were the same as in Example 3) was formed in the same manner as in Example 3. Then the coating agent 25 was cured by irradiation of ultraviolet rays to form a coating

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film (100 $\mu$ m in film thick), thus preparing a tire of Example 5 wherein the bottom and both side surfaces of the longitudinal groove were treated as having water repellency.

#### Example 6

5 A coating agent containing a silicone resin (Tradename "TUV6000", manufactured by Toshiba Silicone Co. Ltd.) was applied to the bottom and both side surfaces of a longitudinal groove of a tire wherein a sine wave (wave height h and wave length f were the same as in Example 4) was formed 10 in the same manner as in Example 4. Then the coating agent was cured by irradiation of ultraviolet rays to form a coating film (100 $\mu$ m in film thickness). There prepared a tire of Example 5 wherein the bottom and both side surfaces of the longitudinal groove were treated as having water repellency.

15 The following Comparison Test 2 was conducted on the above Examples and Comparative Example 1 for comparison, to evaluate the respective characteristics.

#### Comparison Test 2

20 As shown in Fig. 7, a tire 1 of each sample was mounted on a rotation wheel 6, and the aforesaid roller 3 was pressed against the tire from below so that the distance between the shafts of the two became 13 mm shorter than the distance when the two came in contact with each other.

25 Further, as shown in Fig. 9, bristle 70 of a brush 7 was brought into contact with the tire 1 and the roller 3 at

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opposite lateral sides thereof, so as to prevent water fed from a pipe 8 (described later) from flowing out over the lateral surfaces of the tire 1 and the roller 3.

While maintaining this pressed state, the tire 1 and 5 the roller 3 were rotated at a constant speed in the directions shown by arrows in the figure. When the rotation was stable, 13 liter of water per minute was fed between the tire 1 and the roller 3 from a feed port provided laterally of 10 a polyvinylchloride pipe 8 (13 mm in the inner diameter of the pipe, size of the feed port: 5 mm high, 90 mm wide) for five minutes, as shown by an arrow of the alternate long and short dashes in the figure.

Then, measurement was performed for the amount of 15 water (cc) collected by a pail 9 (size of the opening: 345 mm long, 200 mm wide) being placed 5 mm forward from the tire 1.

The pail 9 includes, as shown in Fig. 8, a vent 90 for an efficient collection of water from the tire 1, which is disposed on the rear side thereof, and a cover plate 92 for preventing water collected by the pail 9 from escaping from 20 the vent 90, which is disposed between an opening 91 and the vent 90.

By setting a rotation speed of the tire 1 at the following values to obtain its measurements:

Measurements at 845 r.p.m. (equivalent to 79.6 km/h)  
25 are given in Table 2, those at 1011 r.p.m. (equivalent to 95.2

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km/h) in Table 3, those at 1127 r.p.m. (equivalent to 106.0 km/h) in Table 4, and those at 1272 r.p.m (equivalent to 119.8 km/h) in Table 5. Every table accompanies the decrease rate of water (%) for each Example, which was obtained from the 5 aforesaid equation based on the result of Comparative Example 1.

Table 2

	<u>Water (cc)</u>	<u>Decrease rate (%)</u>
10	Example 3 1533	33.2
	Example 4 1450	36.8
	Example 5 698	69.6
	Example 6 1250	45.5
	Comp.Ex.1 2295	-

15

Table 3

	<u>Water (cc)</u>	<u>Decrease rate (%)</u>
20	Example 3 1570	35.9
	Example 4 1460	40.4
	Example 5 550	77.6
	Example 6 1275	48.0
	Comp.Ex.1 2450	-

25

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Table 4

	<u>Water (cc)</u>	<u>Decrease rate (%)</u>
5	Example 3 1590	37.0
	Example 4 1550	38.6
	Example 5 528	79.1
	Example 6 1300	48.5
	Comp.Ex.1 2523	-

Table 5

	<u>Water (cc)</u>	<u>Decrease rate (%)</u>
10	Example 3 1610	37.8
	Example 4 1600	38.2
	Example 5 509	80.3
15	Example 6 1400	45.9
	Comp.Ex.1 2590	-

Followings are noted by inspection of Tables 2 to 5.

Every tire of Examples 3 to 6 collected much less  
20 water in the pail than Comparative Example 1 at any one of the  
aforesaid speeds. This shows that Examples 3 to 6 are  
excellent in discharging water out of the groove and can  
significantly reduce the amount of water which is not  
discharged from the groove but is transmitted forward in the  
25

rotational direction.

From the results of Examples 3 and 4 having the respective sine wave forms wherein the wave height  $h$  was the same but the wave length  $f$  was varied, it has been clear that 5 the wave length  $f$  is preferably between 5 and 15 mm.

Further, from the comparison between Example 3 and 5, or between Example 4 and 6, it has been clear that Examples 5 and 6 each having the coating film provided on both bottom and the side surfaces of the longitudinal groove, collected 10 less water and exhibited a larger decrease rate of water (%) than Examples 3 and 4, thus being far more excellent in discharging water out of the groove.

#### Examples 7 and 8

A tire of Example 7 was prepared in the same manner 15 as in Example 3, except that a square wave (2 mm in wave height  $h$ , 5 mm in wave length  $f$ ) by changing the mold used for press molding, as shown in Fig. 3(b), was provided on the bottom 11a.

A tire of Example 8 was prepared by forming the same 20 coating film (100 $\mu$ m in film thickness) as in Example 5 on the bottom 11a and the side surfaces of the longitudinal groove of the tire of Example 7.

The aforesaid Comparison Test 2 wherein the rotation speed of the tire 1 was set at 845 r.p.m. (equivalent to 79.6 25 km/h) was conducted on both tires of Examples 7 and 8 to

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evaluate the respective characteristics. The measurements of the decrease rate (%) for Example 7 wherein neither the bottom nor the side surfaces of the groove were treated as having water repellency, are given in Table 6 along with those for Example 3 and Comparative Example 1. Those for Example 8 wherein the bottom and both side surfaces of the groove were treated as having water repellency is given in Table 7 along with those for Example 5 and Comparative Example 1.

10

Table 6

	<u>Water (cc)</u>	<u>Decrease rate (%)</u>
Example 7	1640	28.5
Example 3	1533	33.2
Comp. Ex. 1	2295	-

15

Table 7

	<u>Water (cc)</u>	<u>Decrease rate (%)</u>
Example 8	725	68.4
Example 5	698	69.6
Comp. Ex. 1	2295	-

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25

As seen from the results in Tables 6 and 7, it has

been clear that Example 7 has the ability to discharge water

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out of the groove similar to that of Example 3, and Example 8 has that ability similar to that of Example 5. Hence, both Examples can significantly reduce the amount of water which is not discharged out of the groove but is transmitted forward in 5 the rotational direction.

From inspection of Table 6 and 7, it has been clear that on tires having the same wave form, one wherein the water repellent coating film is formed on the bottom and the side surfaces of the groove, exhibits a further enhanced ability to 10 discharge water out of the groove.

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## CLAIMS

1. A tire for vehicle characterized in that at least a circumferential groove of grooves formed in a tread surface comprises a continuously waved bottom surface whose top does 5 not reach the tread surface, which extends partially or entirely along the circumference of the groove.
2. The tire for vehicle of Claim 1 wherein said waved bottom surface extends over the entire width of the bottom of the 10 groove.
3. The tire for vehicle of Claim 1 wherein said waved bottom surface is in a form selected from the group consisting of a sine wave form, a square wave form, a chopping wave form 15 and a trapezoidal wave form.
4. The tire for vehicle of Claim 1 wherein said waved bottom surface has a wave height ranging from 1 to 4 mm and a wave length ranging from 1 to 150 mm. 20
5. The tire for vehicle of Claim 1 wherein some or all of said grooves formed in said tread surface including grooves having said waved bottom surface are each treated as having water repellency on at least a part of the bottom or side 25 surfaces thereof.

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6. The tire for vehicle of Claim 5 wherein said bottom or side surfaces are treated as having water repellency by forming thereon a coating film containing a water-repellent resin.

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7. The tire for vehicle of Claim 5 wherein said bottom or side surfaces are treated as having water repellency by affixing thereto a sheet containing a water repellent resin.

10

8. The tire for vehicle of Claim 5 wherein said bottom or side surfaces are treated as having water repellency by forming a portion to be a groove with a rubber compound containing a water repellent resin when the tire is vulcanized and formed.

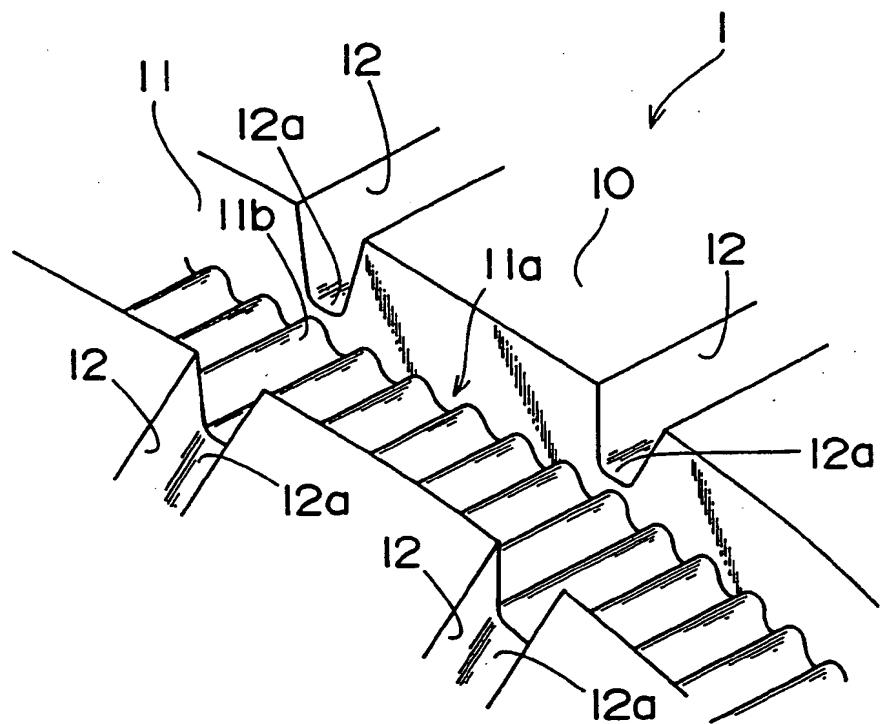
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FIG. 1



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FIG. 2(a)

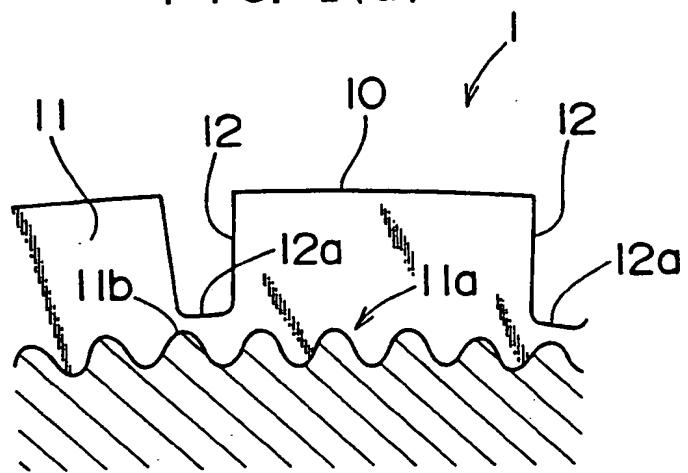
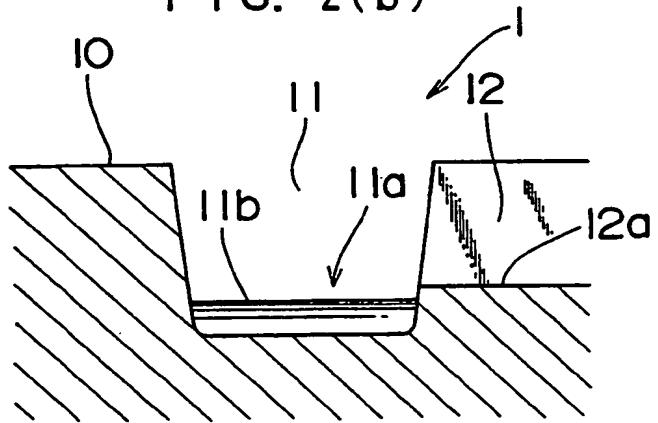


FIG. 2(b)



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FIG. 3 (a)

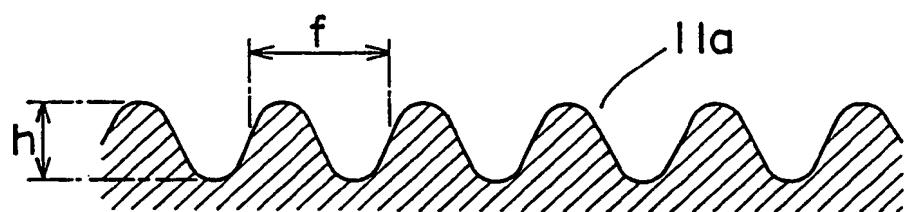


FIG. 3 (b)

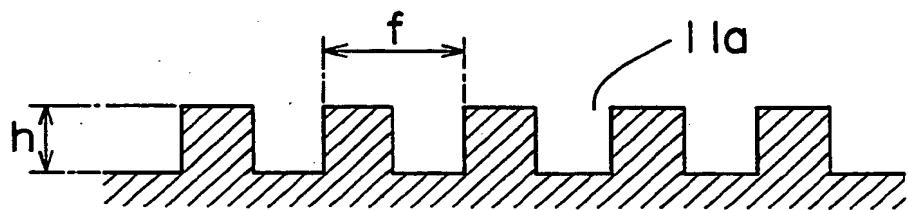
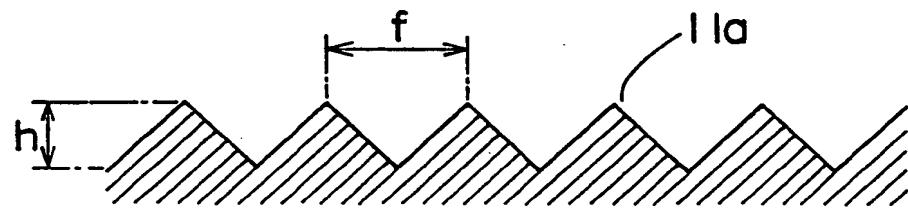


FIG. 3 (c)



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FIG. 4 (a)

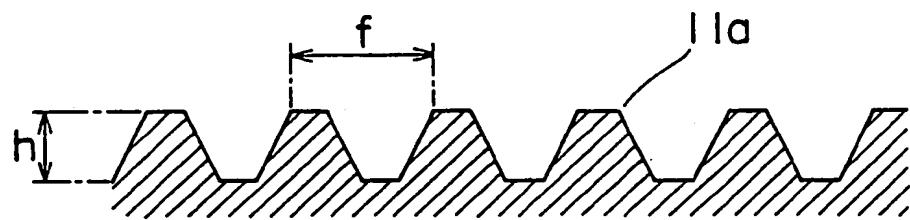
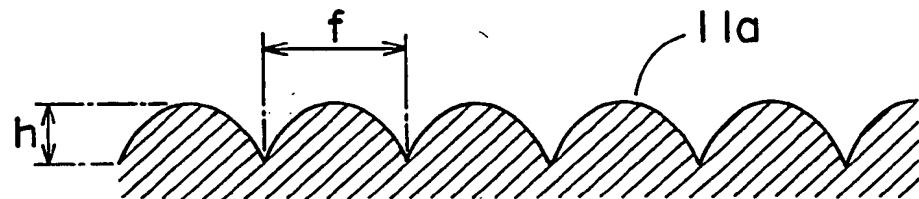


FIG. 4 (b)



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FIG. 5 (a)

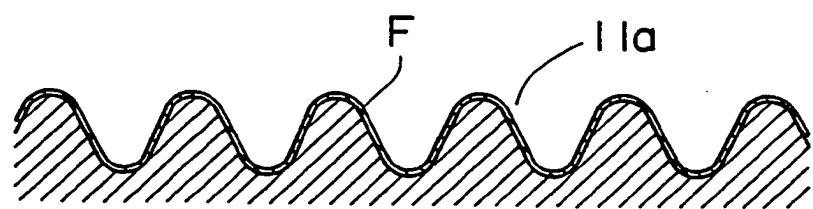


FIG. 5 (b)

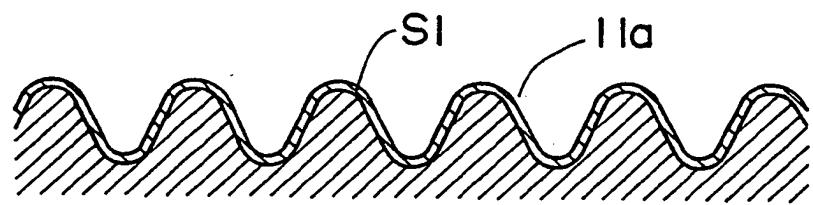


FIG. 5 (c)

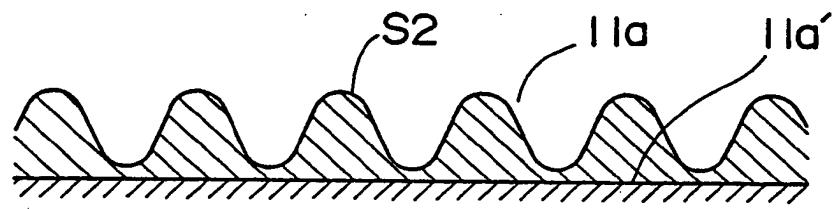
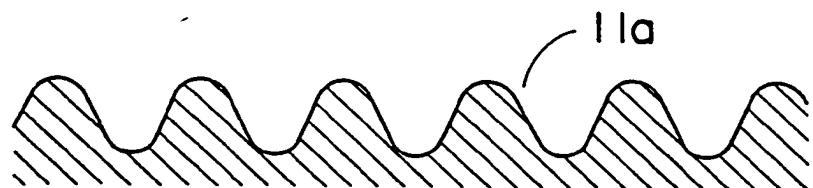
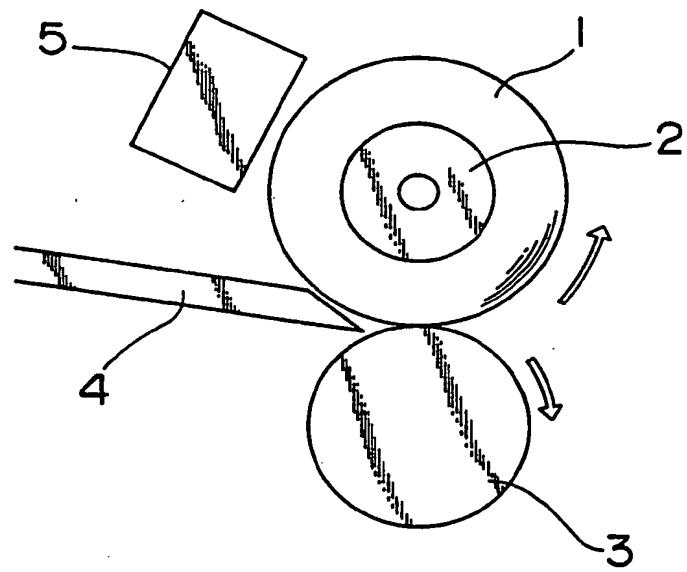


FIG. 5 (d)



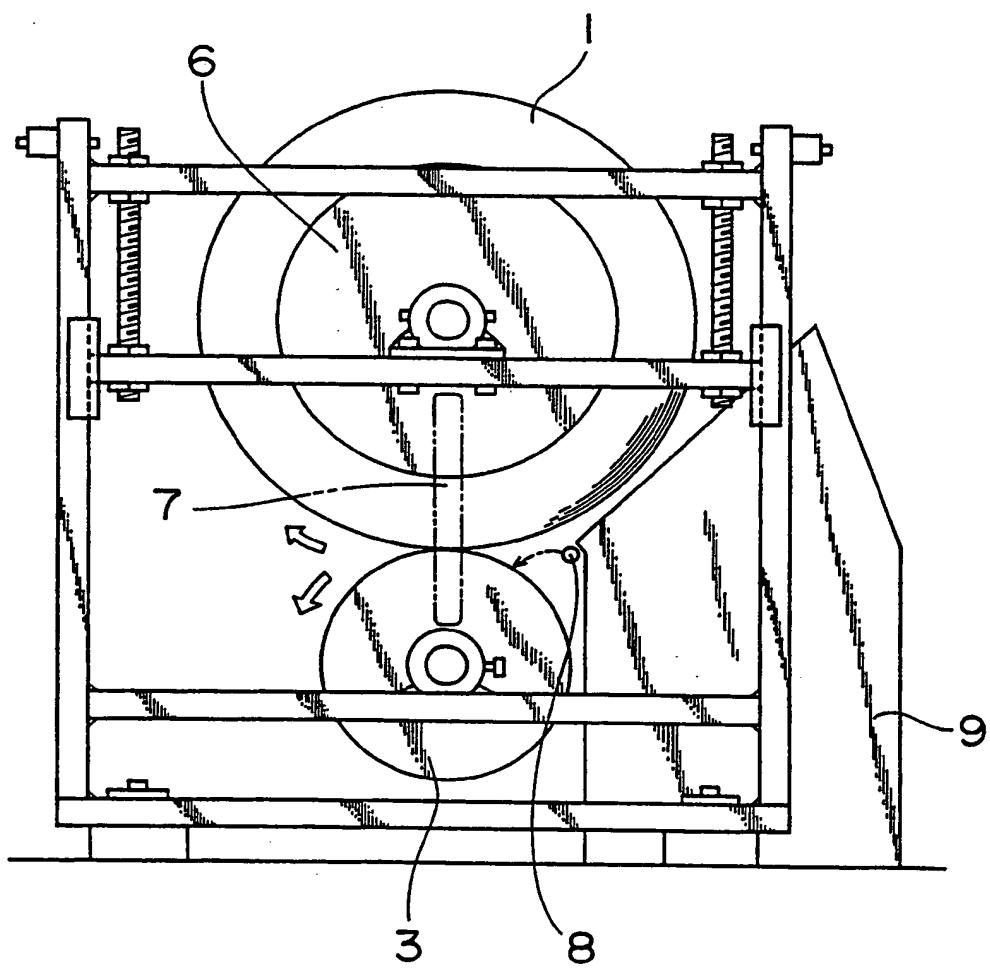
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FIG. 6



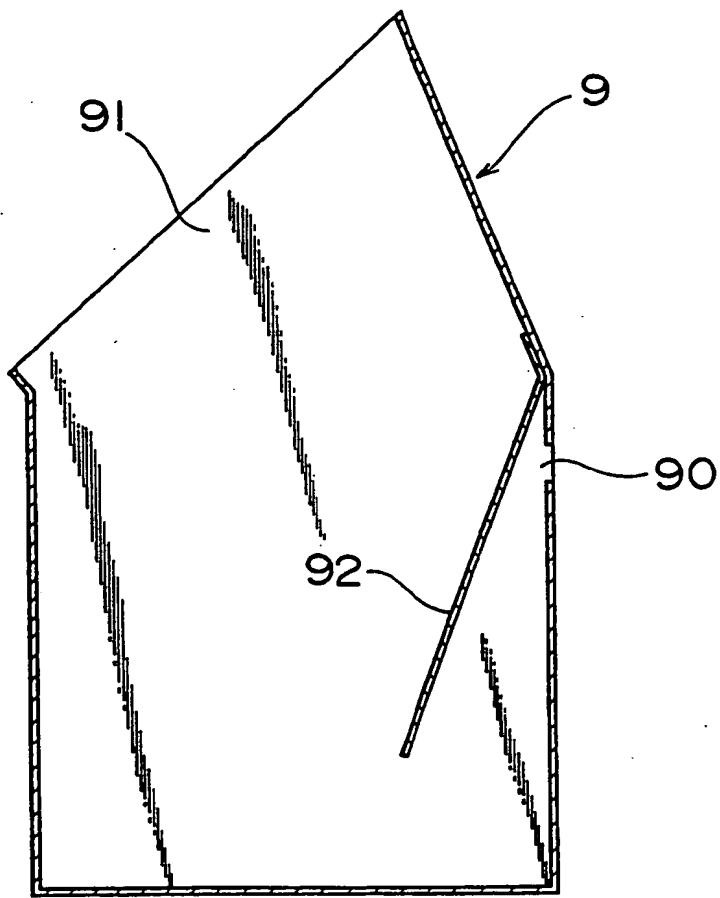
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FIG. 7



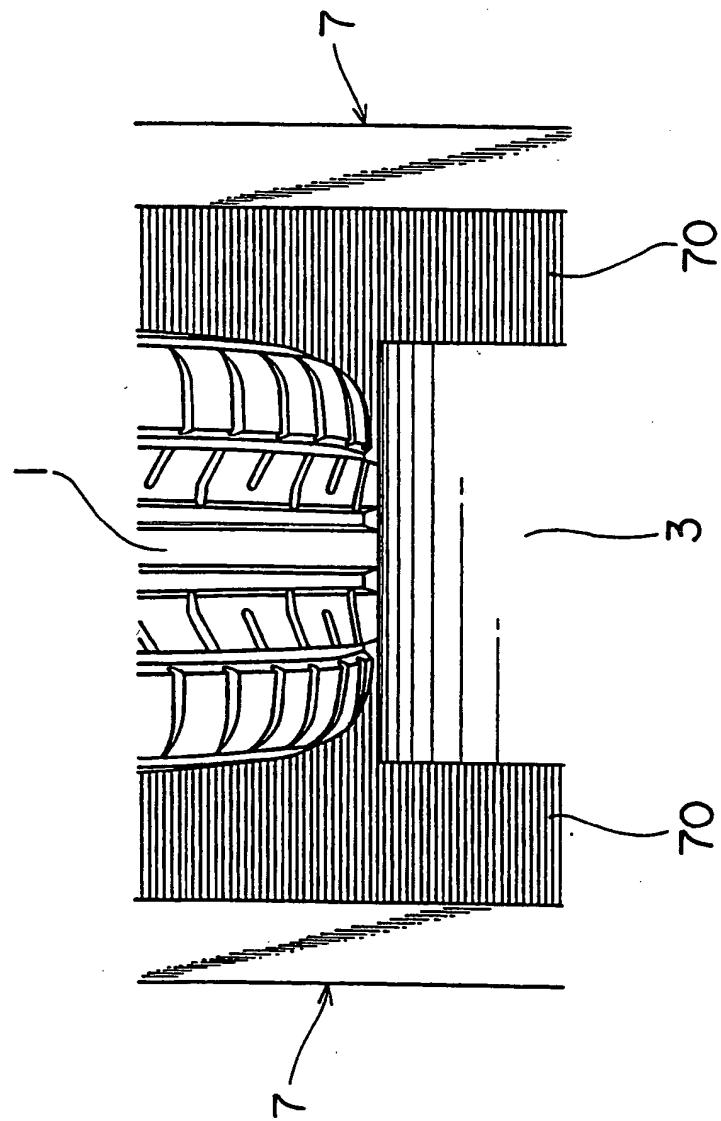
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FIG. 8



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FIG. 9



**INTERNATIONAL SEARCH REPORT**

Int'l. Application No

PCT/JP 94/02229

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 6 B60C11/13

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
IPC 6 B60C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US,A,3 727 661 (G.J.HOKE) 17 April 1973 see column 4, line 1 - line 31; claims; figures see column 4, line 46 - line 57 ---	1-4
X	FR,A,2 470 696 (BRIDGESTONE TIRE CO. LTD.) 12 June 1981 see page 9, line 19 - page 10, line 8; claims; figures ---	1
X	DE,A,36 09 248 (SUMITOMO RUBBER IND. LTD.) 16 October 1986 see page 7, paragraph 2 -paragraph 5; claims; figures; table 1 ---	1-4

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

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Date of the actual completion of the international search

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Date of mailing of the international search report

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## INTERNATIONAL SEARCH REPORT

Int. Jnl Application No  
PCT/JP 94/02229

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE,A,33 36 239 (CONTINENTAL AG.) 18 April 1985 see page 6, line 26 - line 30; claim 8; figure 4 ---	5-8
A	PATENT ABSTRACTS OF JAPAN vol. 7, no. 112 (M-215) (1257) 17 May 1983 & JP,A,58 033 504 (SUMITOMO RUBBER IND. LTD.) 26 February 1983 see abstract ---	5-8
A	EP,A,0 510 550 (CONTINENTAL AG.) 28 October 1992 -----	1,5

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Information on patent family members

Int'l. Appl. No.

PCT/JP 94/02229

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